FIRE HAZARD IMPLICATIONS OF ALTERNATIVE FUEL MANAGEMENT TECHNIQUES - CASE STUDIES FROM NORTHERN PORTUGAL

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ABSTRACT

There is a pressing need for proper fuel management actions in Southern Europe forests. The hazard implications of alternative fuel management options in pine plantations - mechanical treatment with or without physical removal of the residues, prescribed burning, and chemical treatment - are examined in this paper, on the basis of predicted surface fire behavior after developing custom fuel models. Effective short-term reductions in fire hazard were attained only by treatments that physically eliminated the fuels.

Keywords: hazard reduction, fuel management, fuel treatment, Portugal

INTRODUCTION

3% of the total Portuguese forested area is affected by stand-replacement fire each year (Silva, J. 1993). In Portugal, like in most of the Mediterranean Europe, land use changes and increasingly lower levels of biomass use have disrupted the historical fuel cycle and created a fuel buildup problem that is correlated with wildfire acreage (Rego, F. 1991).

Adequate fuel management strategies should therefore be adopted if wildfire hazard is to be kept below acceptable limits. Selection of the most appropriate fuel treatment(s) for a given situation should be primarily based upon sound assessments of the effectiveness of each available technique, which is commonly achieved by examining the respective effects on the fuel-complex structure and associated fire behavior (e.g. Kalabokidis, K. & Omi, P. 1998).

The most common method of fuel management in Portuguese pine plantations is a mechanical treatment where all the slashed biomass is removed, piled and burned outside the stand, a practice that greatly increases costs. Since economical feasibility is an important concern, more cost-effective solutions should be thought of, such as prescribed burning - a technique that remains poorly developed in Europe - or chemical and mechanical treatments that avoid removing the residues. The objective of this study is to compare the effects on fire hazard of alternative fuel management practices, since information on their relative effectiveness is currently lacking.

METHODS

The field work was conducted on mature pine (*Pinus pinaster* and *Pinus nigra*) plantations at 41º 19' N and 7º 44' W, in Serra do Marão, Northern Portugal, where total annual precipitation and mean annual temperature are approximately 1,200 mm and 11º C (Agroconsultores-COBA 1991). Elevation and slope variation of the experimental plots were respectively 950-1000 m and 10-30%.

Nine contiguous plots of 20x5 m were established on three different sites occupied by low (less than 1m height) but dense understory dominated by the shrubs *Erica umbellata* and *Chamaespartium tridentatum*. Height and cover by shrub species on each plot were measured along a 20 m line transect, and later used to non-destructively estimate fuel loads with regional equations (Fernandes, P. & Rego, F. 1998). The understory of the plots was experimentally treated in equal parts (*n*=3 for each modality) with i) low-intensity prescribed burning conducted as a back fire (observed flame length varied between 0.2 and 0.8 m) or a head fire (flame length in the range 0.8 - 1.5 m), and ii) mechanically treated with light equipment (Husqvarna 250 RX and 265 RX) without residues removal, or iii) maintained as a control. In the Marão site, smaller plots of 3x5 m were also sprayed with the herbicide Roundup.

Pre-treatment litter fuels, as well as the fuel-complexes that resulted from the treatments were sampled with 0.25m^2 quadrats; average vegetation height and total cover within a quadrat were recorded before harvesting. The samples were sorted by size class (< 6 mm and > 6 mm), and oven-dried at 85^o C for 48 hours to get dry weights.

Data from a previously (five years) applied treatment was used to compare the effect on fire behavior of removing or not activity fuels, using the same type of mechanical operation as before. A tall (near 2 m) shrub layer of *Erica arborea* established vertical continuity with the overstory canopy, thus precluding the practice of prescribed fire on the stand. Surface fuels were sampled before the treatments, immediately after and five years later, using 1 m^2 quadrats for the pre-treatment elevated fuels and 0.25 m^2 quadrats for litter and the post-treatment downed shrubs.

Site-specific fuel models describing pre-treatment situations and the outcome of each treatment were developed with the FUEL sub-system of the BEHAVE package (Burgan, R. & Rothermel, R. 1984). In addition to the fuel inventory data we used published information from several sources to build the fuel models. Changes in surface fire behavior were quantified with the FIRE1 program of the same system (Andrews, P. 1986), using typical summer conditions in the simulations: a midflame windspeed of 10 km hr^{-1}, and fuel moisture contents of 6% (1-h timelag dead fuels), 7% (10-h and 100-h) and 80% (live vegetation).

RESULTS AND DISCUSSION

Low Understory Plots

Surface fuel loading - understory vegetation plus litter - in the study plots prior to the treatments varied from 13.7 to 27.2 t ha^{-1}, thus representing an important hazard almost entirely based on flammable fine fuels. The immediate and essential effect of the mechanical intervention was to reduce the average vegetation height, and consequently to increase the fuel-complex compactness, which, if expressed by bulk density, increased by a factor of 2 to 3 in relation to the initial situation (Table 1).

Variable	VILA COVA	CAMPEÃ	MARÃO
<6 mm	7.14 ± 1.02 (3.0)	5.70 ± 0.52 (2.4)	6.82 ± 0.31 (3.5)
Total	8.33 ± 1.17 (3.4)	7.73 ± 0.40 (3.0)	10.09 ± 1.55 (4.2)

Table 1. Mechanical treatment effect on the understory bulk density (kg m^{-3}, mean±SE) in the study plots. Values in brackets are the pre-treatment bulk densities.

Fireline intensity was immediately reduced in 33 to 49% following application of the mechanical treatment (Figure 1). However, this benefit was short-lived, and the subsequent fire potential largely exceeded the pre-treatment scenario after the residues were cured.

The chemical treatment was also ineffective, because it modified the nature of the fuel-complex - live portions of plants became dead - without changing its structure, and therefore created an even more hazardous fuel-complex than the mechanical treatment.

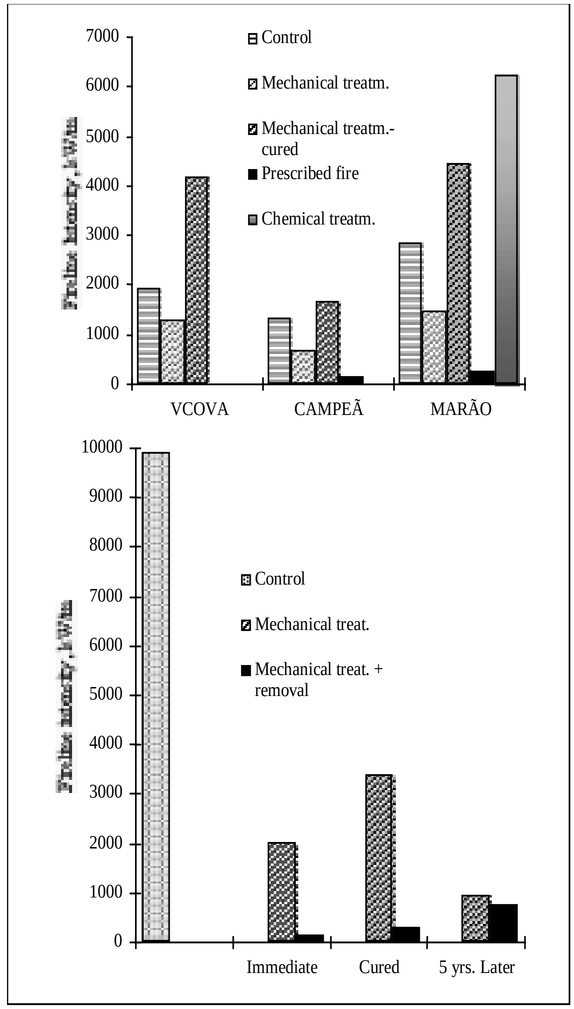

Figure 1. The effect of the fuel treatments on fireline intensity (kW m^{-1}).

Table 2 gives the fuel consumption levels that were observed in the prescribed burning treatments. Results of the simulations concerning prescribed fire are markedly different, since fireline intensity was lowered in 89-98%, making wildfire suppression possible by means of direct attack with hand tools.

Tall Understory Plot

Total surface fuel loading in the tall understory situation reached 27.8 t ha^{-1}, of which 12.9 t ha^{-1} were standing shrub stems thicker than 6 mm. The overall fuel-complex structure suffered a dramatic modification after the shrubs were cut and its compactness increased by a factor of 3.5. Compactness of the remaining fuel

Variable	VILA COVA	CAMPEÃ	MARÃO
Litter (L layer)	0.15 ± 0.07 (86.7)	0.71 ± 0.20 (58.9)	1.17 ± 0.43 (84.4)
Duff (F layer)	5.60 ± 1.85 (27.6)	11.27 ± 2.23 (15.0)	9.81 ± 2.23 (55.2)
Shrubs <6 mm	0.36 ± 0.01 (95.4)	0.44 ± 0.16 (92.5)	1.75 ± 0.52 (88.4)

Table 2. Effect of the prescribed burn treatment: post-burn fine fuel loads (t ha^{-1}, mean±SE) and reductions (in brackets) as a % of the preburn situation in the study plots.

bed further increased after removing the slash and was 5 times higher than in the pre-treated stand. Both modalities of the treatment caused an important decrease in fire hazard, respectively of 80% and 98%. However, it is important to stress that effective control in the event of a wildfire was guaranteed by the second option only. Fireline intensities near 2,000 and 3,500 kW m^{-1}, respectively for fresh and cured residues, would result from not removing the slash. Both situations displayed similar fire behavior near 1,000 kW m^{-1} five years after the treatment. Most of the fine residues left on-site were decomposed meanwhile and shrubs recovery was poor, which suggests that in some situations and where fire-free periods are longer, mechanical treatments without slash disposal can be a viable alternative.

CONCLUSION

Ultimately, the efficiency of fuel management activities is assessed by examining their actual effects on wildfire damage (e.g. Weatherspoon, C. & Skinner, C. 1995). However, fire behavior simulation allows the analysis of alternative scenarios, and can help the decision-making process of fuel management.

When the understory is chemically treated or simply cut and left on-site, the effect can be miscarrying, since more fuel becomes available for combustion, thus conducing to higher heat release and fire intensity. Of all the fuel treatments that were analyzed in this study, only those consisting in physical fuel elimination - prescribed burning and mechanical treatment with slash disposal - were capable of achieving effective short-term reductions in fire hazard.

Because fuel removal is expensive and leads to nutrient depletion, other alternatives to prescribed burning should also be examined, such as lopping and scattering or chipping the slash.

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